TLD Efficiency calculation for heavy ions: a new approach*

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Thermoluminescence dosimeters (TLDs) are solid state detectors widely used in conventional radiation detection and dose verification. The development of ion beam cancer therapy and the research in radioprotection in space stimulated the use of the TLDs for heavy ions dosimetry. The main advantages of this kind of detector, compared, e.g., to ionization chambers, are the small dimensions, ease of handling, no interference on the radiation field and the usability in solid state phantoms. However the response of TLDs with dose is non-linear. It can be supralinear and saturation effects appear as well. The response of these detectors when irradiated with particle beams depends also strongly on the quality of the radiation. For this reason, in order to use TLDs with particle beams, and specifically, to get a prediction of their response in a treatment plan, a model that can reproduce the behavior of these detectors in different conditions is needed.

A new, simple and completely analytical, algorithm for the calculation of the efficiency depending on ion charge Z and energy E has been developed.
The approach investigated is based on the amorphous track structure model and on the knowledge of radial dose distribution for heavy ions D(r) and of the detector response to reference radiation, for this work X-ray, TL_γ. The response of the whole detector has been evaluated starting from the response to a single ion of the beam and considering the contributions of dose from the neighbouring tracks as adding up in a linear regime. This approach is realistic in a low dose approximation.

The relative efficiency R.E. has been derived according to

$$R.E = \left.\frac{S_{HI}}{S_\gamma}\right|_D \tag{1}$$

using S_{HI} and S_γ the integral light sum of detector irradiated with heavy ions and X-ray, respectively.

Since X-ray's response curve is known and the dose deposition is uniform, the signal can be calculated directly from the total dose delivered by the ion. The thermoluminescence caused by ion is derived as

$$S_{HI} = 2\pi \int_0^{r_{max}} TL_\gamma(D(r))rdr \tag{2}$$

where r_{max} is the maximum range of the secondary electrons.

In figure 1 it is shown the agreement of the present model with experimental data. Its main advantage, is that being fully analytical is computationally fast and can be then efficiently integrated in treatment planning verification tools. Furthermore, it is robust against modifications of the radial dose distribution of a single ion in the detector, as well as to different detector response models. A comparison with a statistical method based on Kellerer algorithm [2] has been also done, returning a good agreement.

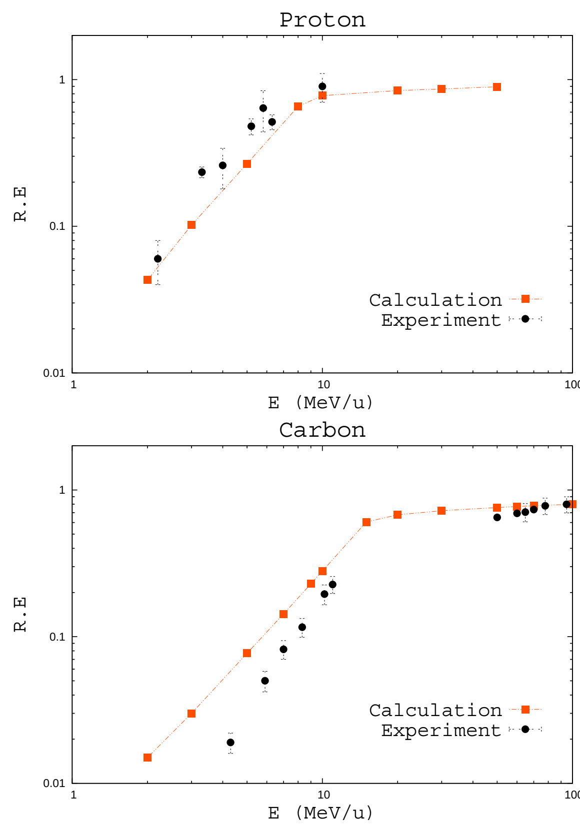

Figure 1: A comparison between experimental relative efficiency data [1] and calculation with the present approach for protons (up) and carbon ions (down).

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References

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[2] S. Greilich et al., Efficient calculation of local dose distribution for response modelling in proton and ion beams (submitted), arXiv:1306.0185v1.